

WORLD CLIMATE RESEARCH PROGRAMME

International Program for Antarctic Buoy (WCRP-IPAB)

White Paper

“Optimal Analysis Products Combining Buoy Trajectories and Satellite-Derived Ice-Drift Fields”

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Preface

The World Climate Research Program's International Program for Antarctic Buoy (WCRP-IPAB), in contrast to its International Arctic Buoy Program (IAPB) counterpart, has compiled a series of much more sparse temporal and spatial coverage of buoy drift tracks with relation to the Southern Ocean sea-ice cover. IPAB must therefore develop a unique strategy for monitoring sea ice and the lower atmosphere with limited resources.

At the “Symposium on Antarctica and Global Change” in Hobart, Tasmania, 13-18 July, 1997, a second meeting of the Ad-Hoc Antarctic Radarsat Geophysical Processor System (A/RGPS) working group was convened (For results of initial meeting see URL: <http://oceans-www.jpl.nasa.gov/ARGPS.html>). At this informal meeting, the status and state-of-art of satellite sea-ice tracking was discussed, together with the implications of long-term large-scale sea-ice motion fields for validating general circulation model (GCM) output fields. This White Paper is the natural offshoot of subsequent discussions with a wide variety of groups, and is a companion to a recent White Paper documenting the ‘state-of-art’ of ice-motion mapping using satellite microwave data (Maslanik et al., 1998). The content of this document is intended to reflect the views of attendees of the Hobart meeting involved with remote sensing of sea-ice dynamics and also those who desire to use such data in their respective studies. Consensus reached at the Hobart meeting was the desire to collectively create a spatial sea-ice drift dataset of widespread benefit in terms of Antarctic modeling and process studies. This objective requires combination of as many individual historical Antarctic buoy datasets over the last decade or so and their synthesis with satellite ice-motion products in order to derive a consistent long-term ice motion record for the entire Southern Ocean.

The purpose of this White Paper is to seek endorsement and support from the WCRP and the IPAB Group for combined efforts between international institutions deploying buoys and institutes developing satellite-derived products. This document also serves as a proposal to WCRP-IPAB for IPAB membership rights for groups contributing spatial ice-drift products derived from new

satellite-data processing technologies. Participation in development of a blended Eulerian ice-motion dataset will be the primary requirement for participation of satellite remote sensing groups seeking IPAB membership and buoy data products. Blended fields of ice motion will be computed by combining traditional buoy drift time-series observations with temporally-spaced, satellite-derived ice-motion fields such that a “optimal analysis” products may be derived and archived for IPAB membership access. Value-added, optimally-analyzed gridded products will contain a mixture of buoy and satellite motion measurements for the period spanning 1978 until the present day. This dataset will be different from the large-scale Lagrangian grids of 3 day Arctic Ocean ice drift presently derived by the RADARSAT Geophysical Processor (RGPS) at the Alaska SAR Facility (URL: <http://www-radar.jpl.nasa.gov/rgps/radarsat.html>).

Background

Techniques have matured over the last several years for gridding and processing Antarctic satellite radiometer and radar images. Datasets to which these techniques have successfully been applied include SSM/I passive microwave data [Agnew *et al.*, 1998; Emery *et al.*, 1997; Kwok *et al.*, 1997; Maslanik *et al.*, 1998; and Liu and Cavalieri, 1998], ERS-1/2 and NSCAT scatterometer data [Long and Drinkwater, 1998; Drinkwater, 1997], and Synthetic Aperture Radar (SAR) data from ERS-1/2 [Drinkwater, 1998a,b] and RADARSAT.

For the purpose of illustration of these techniques in this report, gridded ice motion data sets have been produced from Scatterometer and SSM/I (at 3 and 1 day intervals) for an entire year in 1992 as a test dataset. Coincident field-deployed Argos buoy and drifting ice camp GPS positions in Figure 1 are presently being used to check the validity of the tracked drift vectors from each instrument. Temporally and spatially overlapping SAR motion vector grids have been employed for comparison purposes in order to compare the consistency between the derived small and large-scale motion fields.

Comparisons with ECMWF pressure field data in Figure 2 indicate that Antarctic sea ice drift tracked by these medium-scale resolution images results predominantly from large-scale synoptic pressure fields on timescales of days. High-frequency motion driven by passing low-pressure systems and tidal forcing (over continental shelf regions and shallow water only) is only really captured successfully by Synthetic Aperture Radar (SAR) sea-ice tracking on timescales of 12 hours or less. Synoptic scale sea-ice drift responds rapidly to changes in forcing on timescales of 12 hours or less depending on the location with respect to the coastline (Drinkwater, 1998a). Seasonality of ice drift is linked to the extent of the sea ice within the Weddell and Ross sea basins and the translation of internal ice stresses through the pack ice.

Illustrative Results

Climatological summaries of kinematic and dynamic parameters have been derived which are currently being compared with numerical model simulations of sea ice in the Weddell and Ross Sea sectors. A grid spacing (~100 km) has been chosen for the ice motion product to be consistent with current model grids. The grid resolution may be adjusted and made finer at a future date, as dependent upon the accuracy and precision of the tracked large-scale sea-ice drift. Figures 3 and 4 indicate summaries of austral winter three-monthly climatologies of ice drift in the Weddell and Ross Sea sectors of the Southern Ocean. The Weddell Gyre is clearly resolved in Figure 3 with the key characteristics of the cyclonic (clockwise) gyre motion resolved. Color gradients indicate acceleration of the sea ice as it escapes the coastal entrapment of the Antarctic peninsula and enters the Antarctic Circumpolar Current (ACC). In Figure 4 the extent of the Ross Sea Gyre is delineated with ice leaving northwards, to turn east and flow into the Amundsen Sea. A distinctive

convergence zone occurs along the central axis of the Ross Sea along 190° E. This is the location where old (perennial) ice recirculating from the Amundsen Sea coastal region meets newly formed ice driven offshore from the Ross ice shelf by katabatic winds.

Figures 5 and 6 show dynamical summaries corresponding with the identical 3-month mid-winter period (Jul.- Sept., 1992). Mean 1-day net shear strain (strain invariant E_{II}) is represented in a colorized gridded plot overlaying the climatological mean 1-day motion field of the sea ice. Regions of significant climatological shear occur primarily in the central Weddell and Ross gyres. High shear also helps delineate the axis of the Antarctic divergence in some parts of the sea ice cover. In these regions, the separation between the coastal “east wind drift-” and ACC-dominated drift regimes are characterized by zonally extended regions of intense shear. Other important zones of high shear occur in the Ross Sea sector. At the western margin of the Ross Sea, rapidly produced new ice exits the Terra Nova Bay polynya in the coastal current, with large shear values captured along the coast. In addition, at the northern limb of the Ross Gyre, where some of the highest sea ice drift velocities are experienced, the largest pole of winter shear strain is measured.

Figure 6 shows the resulting opening and closing (scaled in %/day x 10) computed from the ice deformation. Areas of sustained climatological opening/ closing are consistent with areas of production of new sea ice, and with zones of intensified ridging (also observed in SAR images). Net opening is observed in a number of known regions of persistent coastal polynyas. These are found off the Amery ice shelf, in Terra Nova Bay, off Cape Norway and the Filchner-Ronne ice shelf, and around parts of Wilkes Land. The two most intense offshore openings occur in the region of maximum sea-ice extension in the Ross Sea, and in a small area of the Amundsen Sea.

Conclusions

Many of the requirements of GCMs and process studies in Antarctica can be satisfied by a climatological, gridded ice drift dataset which blends satellite and buoy-tracked ice motion data. Volumes of data are small enough, and algorithms are presently fast enough, to permit generation of multiple years of ice motion vectors with a fairly small computational burden (Maslanik et al., 1998). Since most data comparisons to-date have used IABP-derived Arctic drifter data, some additional work is required to further assess performance of the satellite ice-motion products in the Antarctic. Nonetheless, merged Arctic basin SSM/I and buoy products indicate a significant improvement over independent satellite ice-motion fields, especially in the regions of interest of the buoy investigators where highly weighted buoy measurements have been used to improve the spatial details of the satellite-derived drift field. In this manner, the resulting merged drift field offers a significant advantages over the individual products themselves.

It is proposed that optimal interpolation be undertaken by IPAB members involved with development of satellite-tracked datasets, in conjunction with existing IPAB members willing to submit buoy data for incorporation in the final optimally-interpolated products. Due to errors in satellite tracking, gridded fields are expected to be most representative of natural drift conditions in regions where buoys are deployed. Thus, the help of the WCRP-IPAB community is solicited to achieve processing of a “value-added” climatological dataset spanning to period of useful satellite data from 1978 - present day.

References

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Related URL's:

RADARSAT SAR Sea Ice Studies

NASA-Supported ADRO RADARSAT Science Investigation Interim Report:
<http://www.asf.alaska.edu/adro/drinkwater.html>

Ongoing Antarctic activities related to RADARSAT and RGPS:
<http://oceans-www.jpl.nasa.gov/mrd/ARGPS.html>

All Ongoing RADARSAT sea-ice investigations:
http://radarsat.space.gc.ca/ENG/ADRO/Projects_Awards/INT_NASA/sea_ice.html

Scatterometer Sea-Ice Tracking

Example of Scatterometer ice tracking:
http://oceans-www.jpl.nasa.gov/mrd/NSCAT_PR#2.html

NSCAT Antarctic Sea Ice Motion Movie:
http://oceans-www.jpl.nasa.gov/mrd/Images/NSCAT_movie.gif

NOAA/NASA AVHRR Polar Pathfinder

SSM/I Ice Motion:
<http://polarbear.colorado.edu>

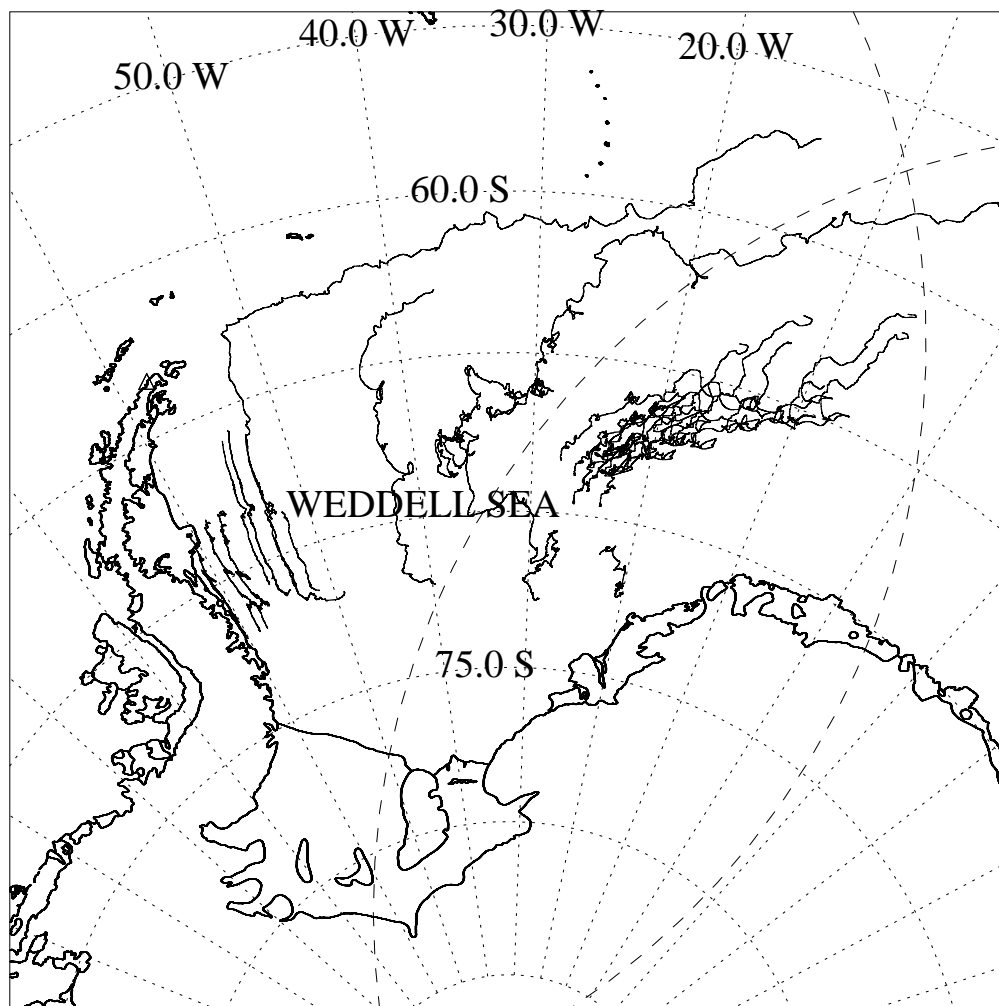


Figure 1. Trajectories of drifting buoys deployed in the Weddell Sea, Antarctica between 1990 and 1993 [data courtesy of Steve Ackley, Doug Martinson, Timo Vihma and Christoph Kottmeier]. Dashed arcs indicate limits to satellite synthetic aperture radar data reception at the German Bernardo O'Higgins and Japanese Syowa stations.

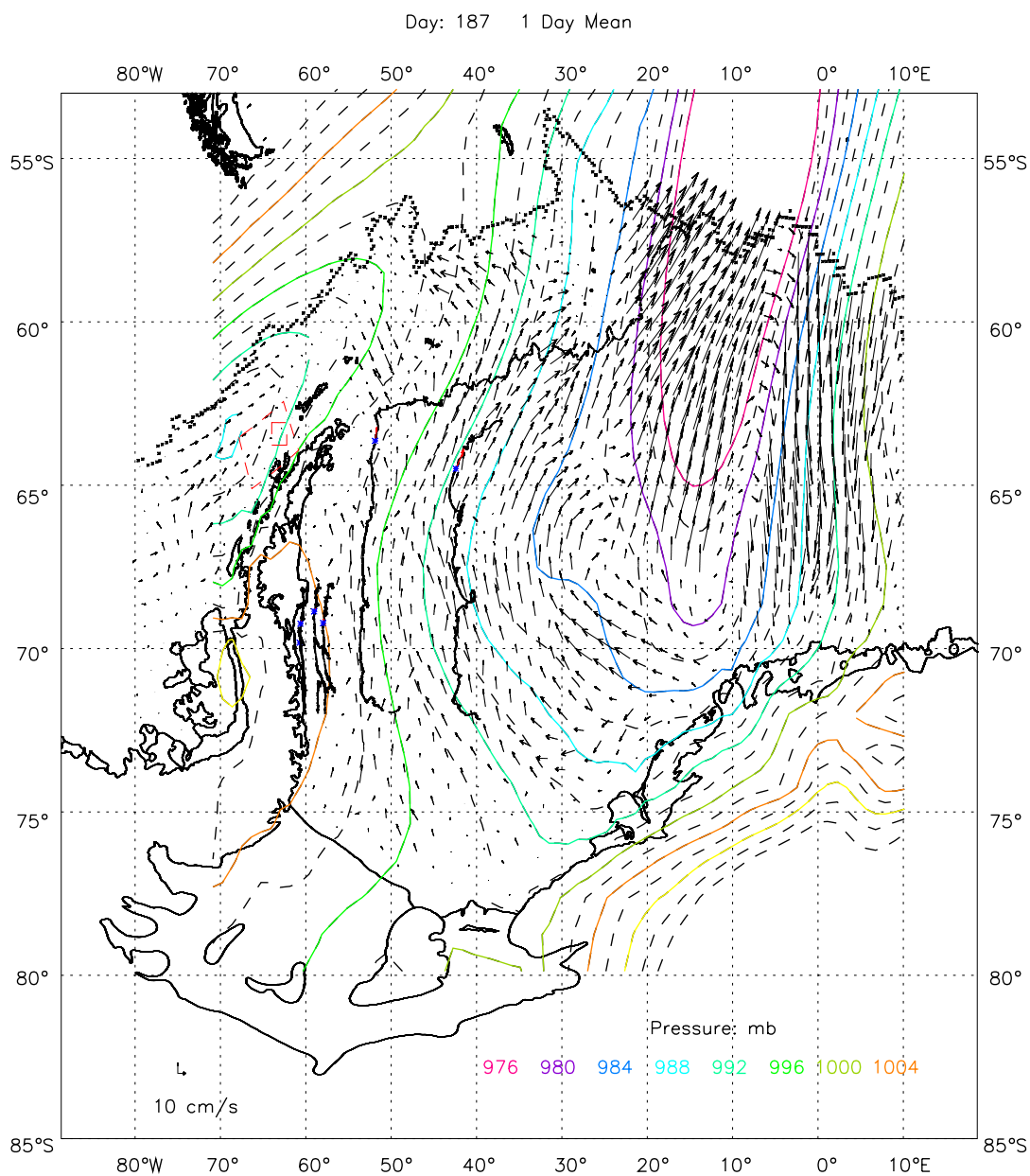


Figure 2. 1-Day SSM/I ice motion and mean ECMWF surface air pressure field for Day 187 (July 5) in 1992 in the Weddell Sea, Antarctica. A typical low pressure system dominates the forcing pattern, and the ice drift field responds accordingly. Buoy vectors are highlighted in red.

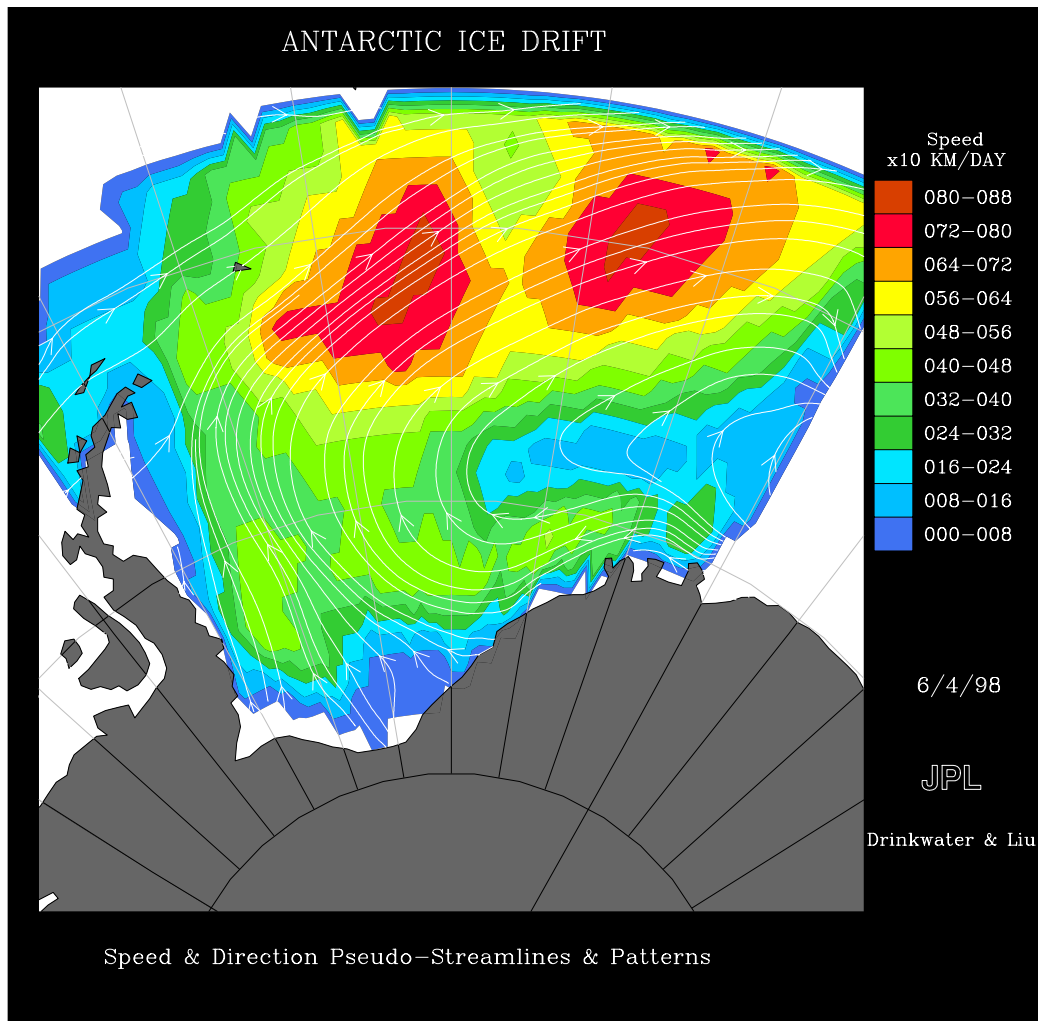


Figure 3. Weddell Sea climatological mean 1-day ice drift, derived from July - September, 1992 SSM/I 85 GHz image data. Colors indicate spatial variations in the drift speed and the white arrows indicate streamlines of drift. Convergence and divergence are indicated by narrowing or spreading of the streamlines, respectively.

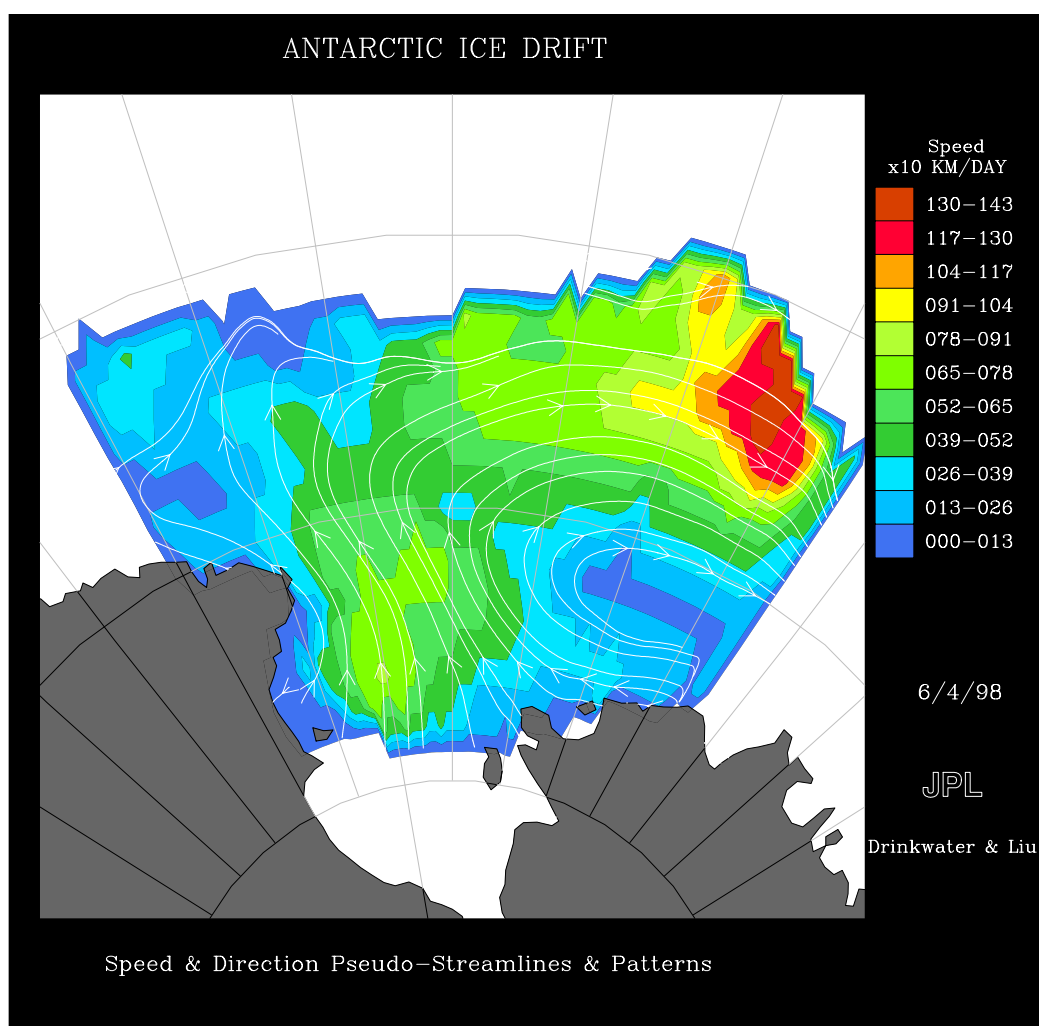


Figure 4. Ross Sea 3-month climatological mean 3-day sea-ice motion, derived from July-September, 1992 ERS-1 Scatterometer image data. As in Figure 3, colors indicate spatial variations in the drift speed and white arrowed lines indicate the direction and streamlines of drift.

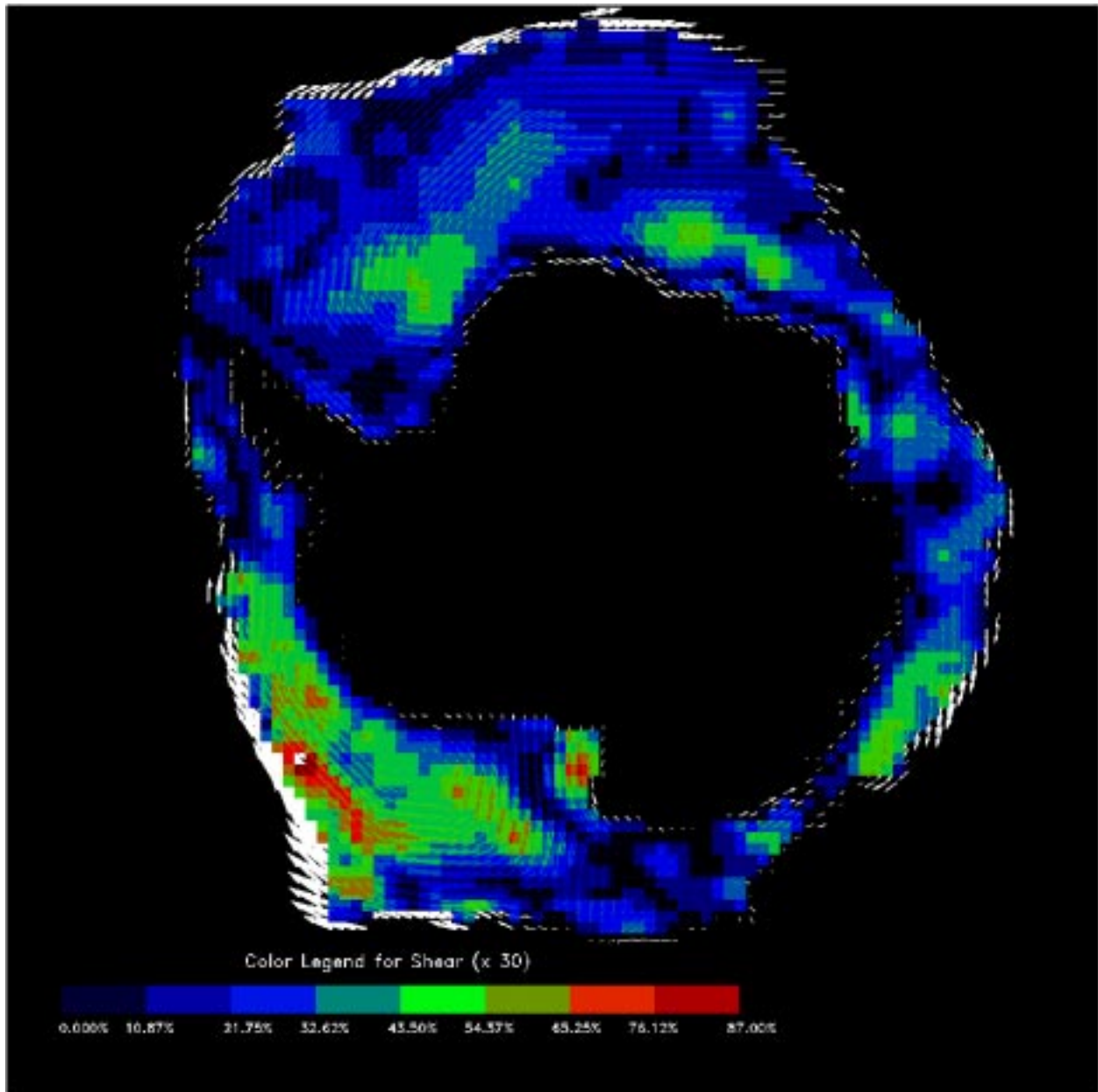


Figure 5. Climatological net shear strain (%/day x 30) for the 3 month austral winter period from July - Sept., 1992. The color scale indicates opening and closing in boxes of 10 x 10 pixels each averaged over an area of 4 boxes. Resampled pixel spacing is ~10 km.

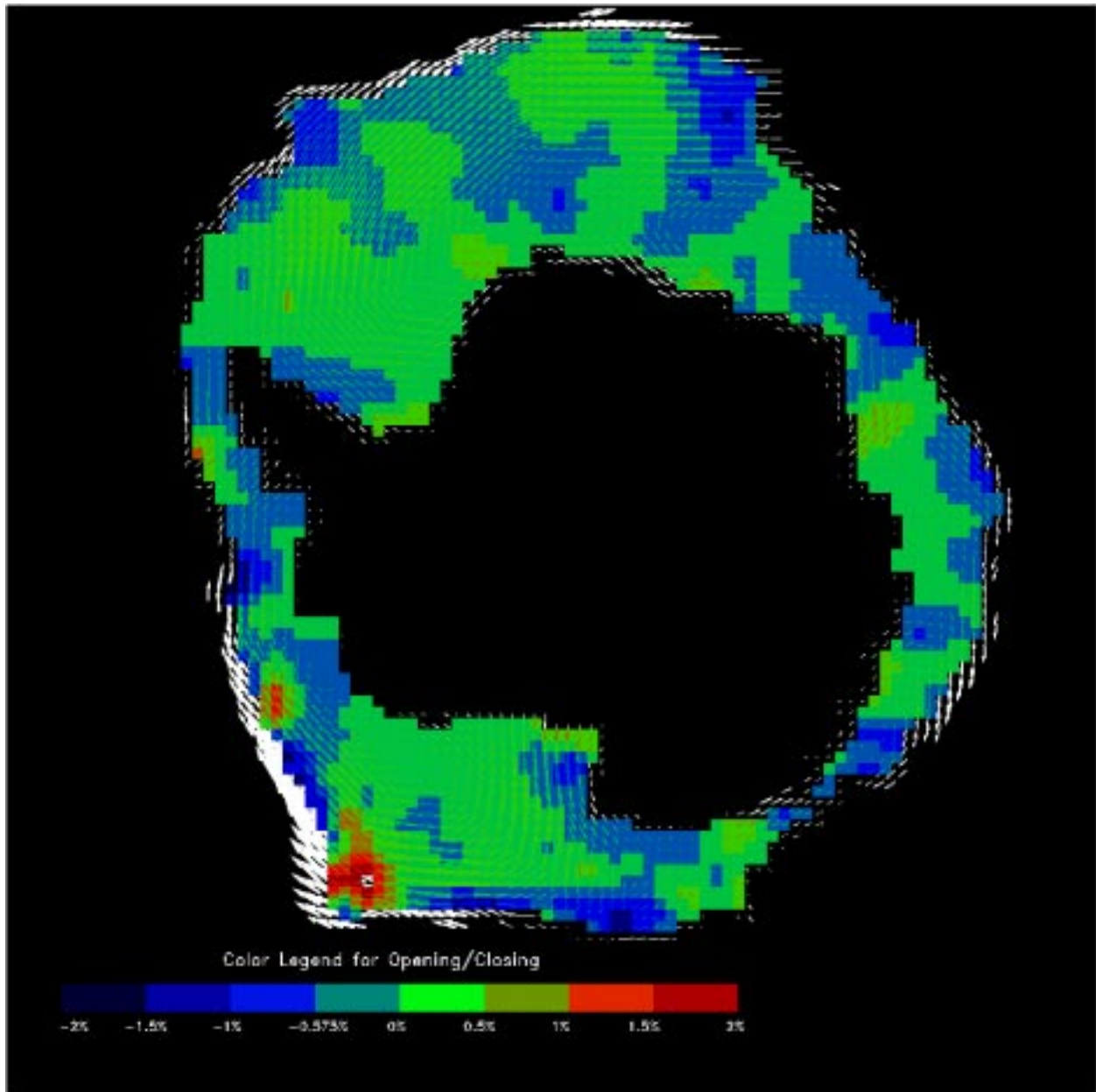


Figure 6. Climatological net 1-day opening/closing during the period July - September, 1992. The color scale indicates opening and closing in boxes of 10 x 10 pixels each averaged over an area of 4 boxes. Resampled pixel spacing is ~ 10 km.